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THE GERMAN ARTIFICIAL EARTH SATELLITE PROJECT [Projekt ...]

by

W. von Maydell Nov. 1963 12 p refs Transl.

into ENGLISH from ... Presented at the 3d European Space Travel Congr., ~~Stuttgart~~, May 1963

Double code 1148407

by Holman (John F.) and Co.

Translation of "Projekt eines deutschen Satelliten"

from Raketentechnik und Raumfahrtforschung, Vol 7, No. 3, 114-118, 1963 v. 7, no. 3 p 114-118

(Stuttgart),

[redacted]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,

WASHINGTON, D.C. November 1963

[redacted]

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THE GERMAN ARTIFICIAL EARTH SATELLITE PROJECT[1] /114

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12475 author

This paper describes the design of the first German satellite and its application in space research. A survey of the power supply, attitude control, stabilization, and telemetry systems is given. The possibilities of its use as a communications, meteorological, or geodetic satellite are described.

AUTHOR

The first German artificial earth satellite will be designed as a versatile instrument for solving scientific problems and performing commercial tasks. Since the scientific problems of space travel are of primary importance, the satellite will be used for several years for research in this area. At preplanned distances from the earth it will continuously acquire data and make observations that will be used in the solution of problems of space travel technology and other related research. Replacement of the scientific instruments by suitable equipment will allow the satellite to be used for commercial assignments such as message transmission, earth surveys, navigation, and meteorological observation.

The design of the first German artificial earth satellite began with research on the basic problems involved in: a) the construction of a /115
capsule for space research instruments and provision of the necessary power for temperature control, position indication, and space orientation equipment; b) data transmission from the satellite and reception of command signals from the ground control station; c) insertion of experimental data and material specimens into a reentry capsule and launching it from the satellite to earth for recovery with contents undamaged by launch, trip or landing; d) later commercial use of the satellite that must not be restricted by the former research mission. The following data and characteristics have been included in the plans for the first of five satellites:

The orbit will be elliptical with an inclination of about 15° toward the earth's axis; the distance from the earth will be 400 km at the perigee, and 900 km at the apogee. The lifetime is expected to be about four to five years. The weight of the

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[1]Translated from Raketentechnik und Raumfahrtforschung, 3, 1963.

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satellite will be about 1,500 kg of which 1000 kg are allocated for the structure and auxiliary equipment, 250 kg for research instruments, and 250 kg for the reentry body and the instrument capsule. Power will be supplied by a solar generating plant. The axes of the satellite are stabilized in relation to space and the symmetrical axis is directed at the sun while the other two coordinate axes will be held in their directions with the aid of two conspicuous stars in the vicinity of the ecliptic poles.

Space orientation of the axes is accomplished with the aid of a system of sun and star sensors. The axes are alined and stabilized in the predetermined directions by gas reaction and ion steering drives.

The satellite body contains a central operations compartment and two compartments for the research instruments. The reentry body with the instrument capsule is joined to this. Upon command the reentry body separates from the satellite, and is recovered by aerial capture or retrieval from the sea. The satellite, however, remains in its orbit. All details of the first German artificial earth satellite are planned to secure the best possible reliability, adaptability for a variety of scientific problems and commercial tasks, lightweight and compact body structure, and durability of the auxiliary equipment.

The proposed satellite will consist of the following principal components: satellite body, reentry body with instrument capsule, power generating plant consisting of an energy converter and a solar mirror, solar and star sensors, gas reaction and electrical drives, extension mechanism for the energy converter, and containers for the converter propulsion fluid and propellant gases (Figure 1). The two main parts of the satellite, the body and the energy converter, are assembled in the shape of a bar bell with the solar mirror mounted at the center of gravity of the system. This arrangement of the components minimizes the angular momenta about the center of gravity, which may be caused by various disturbing forces (Figure 2). The gas reaction and ion drives mounted on the energy converter have the longest dimension of the satellite for leverage purposes. An additional advantage of this location is that the fluid lines and electrical leads can be kept short. The sensors are mounted behind a heat shield near the steering drives above the tip of the conical radiator. A complementary coarse sensor, mounted next to the reentry body, surveys space in the direction opposed to the sun.

On both sides of the radiator, pairs of gas and ion drives are provided on a level with the center of the absorber. They will be used to control roll about the sun-oriented symmetrical axis of the satellite. The extensible arms on which the drives are mounted to increase their angular momenta lie initially beside the radiator and are held in this position by the outer satellite shell.

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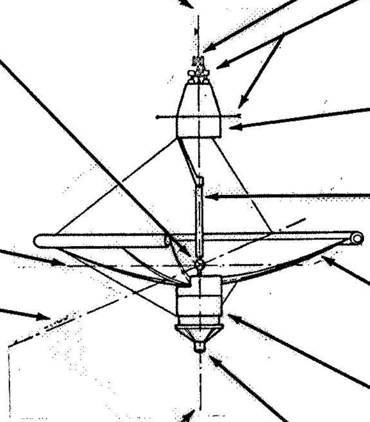


Figure 1. Schematic of the Proposed Satellite and Equipment

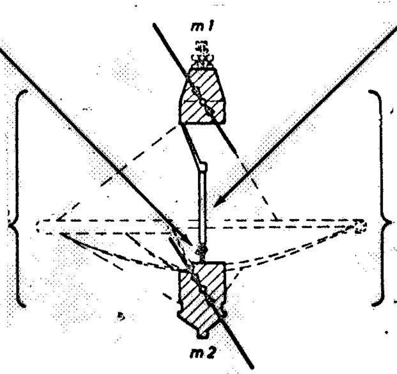


Figure 2. Mass Distribution and Disturbing Forces

Work fluid and propellant gas reservoirs are placed inside the heat exchanger and on the satellite body in the shade of the energy converter in the center of the solar mirror.

This arrangement for the positioning of the satellite components and the orientation of the satellite axis toward the sun places the satellite body in the shade of the solar mirror. The fact that the satellite is not exposed to the sun is an advantage since it facilitates cooling of the operating and measuring compartments, which is made necessary by the heat generated in the instruments. /116

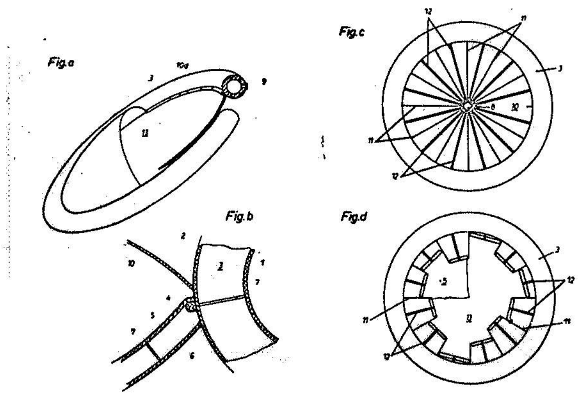


Figure 3. Principle of Reflector Construction

The solar mirror will unfold after a time interval during which a coarse thrust system can stop any rotary motion of the satellite that may have been caused by the separation. The unfolding will occur in the following manner (Figure 4).

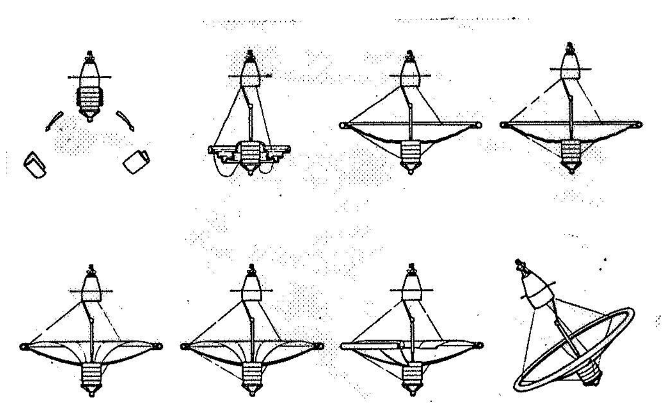


Figure 4. Opening of the Parabolic Mirror

1. The energy converter which, until the destination has been reached, is part of the satellite module, is placed near its final position by a telescopic mechanism,

2. Pitch and yaw motions of the satellite are reduced as much as possible by the action of the gas jets,

3. The toric stabilizer lobe is inflated with compressed gas,

4. Formation of expanded plastic foam from material contained between the double walls of the torus is begun,

5. After the foam in the torus has solidified, the energy converter is moved to its final position, which tightens the guy wires of the torus,

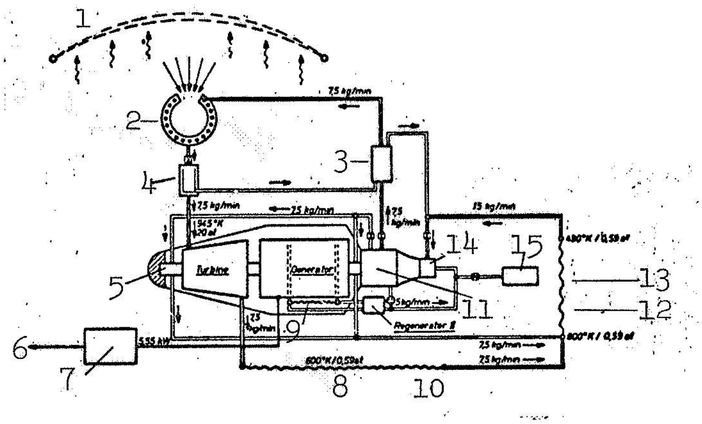
6. Compressed air is blown between the aluminum-coated reflector foil and the cover foil; the reflector foil assumes the shape of a paraboloid,

7. The plastic foam base in the double-walled mirror is made to swell and solidify, and

8. The cover foil is cut off by embedded heat wires, and then rolled up by built-in springs.

The diameter of the mirror with the torus is 10.3 m, the depth of the paraboloid is 1.19 m, and its focal length is 4.75 m. The electric power generating plant is put into service after the mirror axis has been pointed toward the sun. About 75 minutes pass from the beginning of operation to full charge of the regenerator when the generating plant can be put under full load. For this reason the start of generating operation will be timed to coincide with the satellite's exit from the earth's shadow and entry into that part of its orbit which is exposed to the sun.

The energy converter consists of absorber, turbo-generator (homopolar induction generator), condensate pump, separator, and radiator (Figure 5). The energy or work fluid is mercury used in a Clausius-Rankine cycle. The absorber (mean operating temperature 675° C) is a hollow sphere, coated on the inside with a grid of titanium sheet strips. The water-tube type boiler is embedded in lithium hydride which serves the satellite as heat accumulator for the passage through the orbital shadow zone. The absorber aperture closes automatically in the earth's shade and in case of overheating, while the absorber itself transfers heat from the focal plane of the mirror to the generating plant. The mercury is heated, vaporized, and then superheated in the radiator. Then, after passing through the separator for removal of the liquid phase, it enters the turbine where it loses its pressure by performing work. It then condenses in the first section of the radiator and is undercooled in an immediately adjoining cooler to avoid cavitation. A combination jet and centrifugal pump returns the condensate to the absorber. Turbo-generator and pump combination are assembled in one vacuum-tight block. Mercury is also used for the generator radiator and for lubrication of the bearings; for these purposes it flows through special tubes which are connected to the main circulation system. The radiator consists of a pipe system with cooling fins and sheet steel strips to protect the pipes



1-Reflector; 2-Absorber-boiler, 41.2 kw transferred to working medium; 3-Regenerator; 4-Separator; 5-Mercury lubricated bearing; 6-Output five kw; 7-Voltage and frequency regulator; 8-Heat exchanger, Part I, condenser; 9-Generator cooler (radiator); 10-Heat to be dissipated, 35.6 kw; 11-Centrifugal pump; 12-Heat to be dissipated, 2.49 kw; 13-Heat exchanger, Part II, cooler; 14-Jet pump; 15-Reservoir.

——— Mercury Operation Circulation
═══ Mercury Lubricant Circulation

Figure 5. Satellite Power Generating Plant Components

from perforation by meteorites. If perforation should occur, the pipe would be cut off from circulation by automatic valves.

The generating plant furnishes 5 kw during the life of the satellite. The output current can be either all three-phase 110 v ac or part of it may be 28 v dc. The specific output of the plant (including the solar mirror) is 1.25×10^{-2} kw/kg and its theoretical efficiency (incident solar radiation divided by output) is about 5 percent.

A system of three types of sun and star sensors orients the satellite axes in space (Figure 6). The coarse sensor measures the deviation of the satellite symmetry axis from the direction of the sun with an accuracy of $\pm 1^{\circ}$. The fine sensor improves the accuracy of the measurement to about 1' of arc and maintains the correct orientation to ±15' during /117 the life of the satellite. The star sensors by guiding on two stars make it possible to aline one of the coordinate axes of the satellite with the pole of the ecliptic to $\pm 1^{\circ}$.

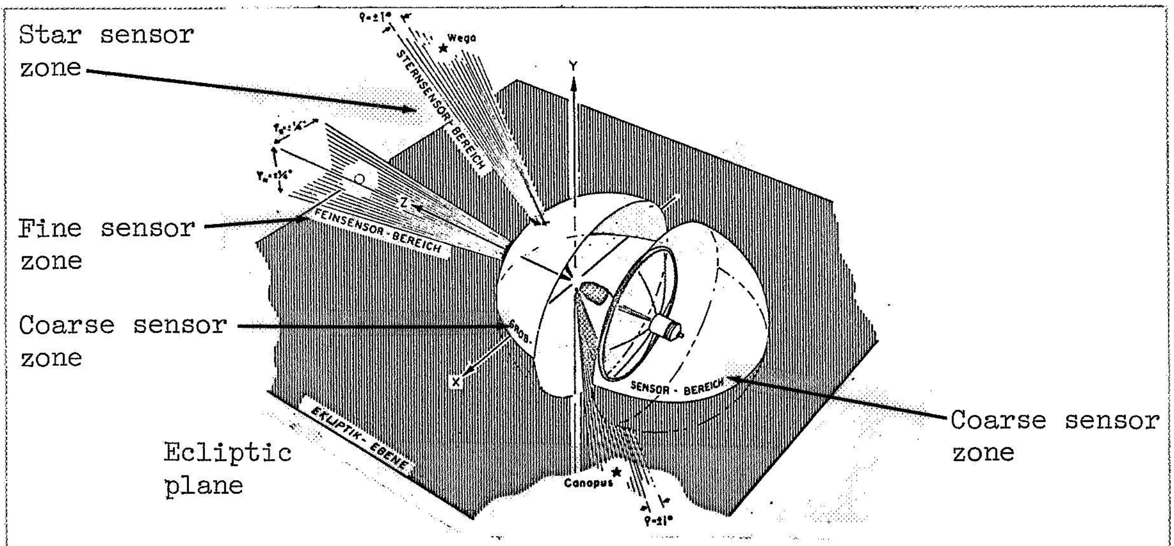


Figure 6. Sensor Zones of the Satellite

These axes are perpendicular to the axis of symmetry. Coarse and fine vernier engines (thrust systems) which are shown schematically in Figure 7 orient and stabilize the axes in the desired directions.

Nitrogen-operated steering engines with a thrust of 20 to 40 pond[1] form the coarse vernier system (coarse thrust control system). This system goes into action when the satellite enters into orbit, during starting operations, and if external forces cause complete disorientation. The fine vernier engines (fine thrust system), however, operate continuously during the satellite life to compensate for effects of disturbing forces. It is planned to use ion propulsion for these vernier engines. They require about 1.8 kw and their thrust is about 1 pond. The cylindrical satellite body consists of three parts. The part nearest the mirror is the operating compartment, the other two are the first and second measuring compartments. The latter carries the reentry body with the instru- /118
ment capsule. The compartments are vacuum-tight and are fastened on a hollow axle on which they can be rotated and held in position with an accuracy of $\pm 1/2^{\circ}$ through 180°. Wherever necessary, measuring and experimental apparatus in the instrument compartments are mounted in swivel bearings so that they can observe in any desired direction in space. In all compartments a nitrogen atmosphere under a pressure of 1-2 atm is maintained at a temperature between 20° C and 50° C by an air conditioner with a 1.4 kw cooling capacity. Table I shows how this arrangement of the first satellite will be modified in later years.

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[1] Metric force measurement. 1 pond ≈ 981 dynes.

Table 1. Specifications for the First Series of German Artificial Earth Satellites

Satellite No.	Orbit	Generating plant	Drives	Telemetry	Body	Recovery
1.1 - a 1.1 - b	Elliptic orbit. Perigee: 400 km Apogee: 1000 to 2000 km Polar route with 15° inclination	Solar turbo-generator Solar turbo-generator	Spin and attitude stabilization	Five channel, 20 data/sec, twin-transmitter system with tape storage. Transmit once per orbit	Modular construction. Cylindrical body. Reentry capsule	Reentry capsule. Parachute
1.2 - a 1.2 - b	Elliptic orbit. Perigee: 400 km Apogee: 1000 to 2000 km After orbit change: 3000 km	Solar turbo-generator Solar - thermionic	Spin and attitude stabilization: Ion drives. Orbit change: Solid fuel propulsion	10 Channel, 20 data/sec, twin-transmitter system with tape storage and one interrogation per orbit	Modular construction. Cylindrical body. Separable reentry body with flaps	Reentry body with flaps. Parachute
1.3 a - 1.3 a -	Elliptic orbit. Perigee: 400 km Apogee: 1000 to 2000 km Orbit changes with continuous propulsion, spiral path	Solar - thermionic Solar - thermionic	Spin and attitude stabilization: Ion drives. Orbit changes: Plasma drive	10 Channel, some with 2000 or more data/sec if required. Twin-transmitter system with tape storage and one interrogation per orbit	Modular construction. Cylindrical body. Separable reentry glider	Reentry glider. Parachute-aided landing

Table 1 (Continued)

Satellite No.	Orbit	Generating plant	Drives	Telemetry	Body	Recovery
1.4 - a - b	Elliptic orbit. Perigee: 400 km Apogee: 1000 to 2000 km Space probe transition: 50,000 km	Solar - thermionic Nuclear turbogenerator or MHD	Spin and attitude stabilization: Ion drives. Space probe transition: Plasma drive	10 Channel, some with 2000 or more data/sec if required. Twin-transmitter system with tape storage and one interrogation per orbit	Modular construction. Separable glider	Reentry glider, parachute, aimed landing
1.5 - a - b	Elliptic orbit. Perigee: 400 km Apogee: 1000 to 2000 km Space probe transition: 100,000 km	Nuclear turbogenerator Nuclear - thermionic	Spin and attitude stabilization: Ion drives. Space probe transition: Plasma drive	10 Channel, some with 2000 or more data/sec if required. Twin-transmitter system with tape storage and one interrogation per orbit	Reentry glider, construction	Reentry glider, aimed landing

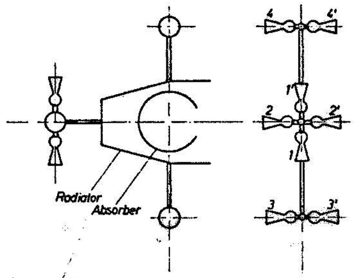

Figure 7. Vernier Engine Arrangement for Attitude Control

While the first satellite has no propulsion for orbital change, it is planned to equip the next one with a solid fuel drive. It is planned for this satellite to attain in increments by Hohmann transitions an orbit 3,000 km beyond the standard orbit with a perigee of 400 km and an apogee of 900 km. The behavior of steering and position-stabilizing systems during the propulsion phase, and problems of space rendezvous will be studied with the aid of these orbit changes. In addition data will be obtained at varying distances from the earth. Electrical propulsion is being considered for the third and fourth satellites. The drive will operate for a short interval during every time in perigee, thus extending the orbit in apogee further and further until an elliptic space probe trajectory is achieved.

For the fifth satellite an electric propulsion unit with an efficient nuclear generating plant is in the planning stage. The elliptic orbit will be changed gradually until escape velocity is reached. It has been mentioned that the satellite is suitable for modification for use in communication, weather forecasting, etc.

Particular advantages are that the efficiency of the generating plant is very high by comparison with that of previously built satellites and the attitude stabilization is sufficient for most applications. It is possible, however, to attain by currently employed means still higher precision of attitude stabilization if the need should arise.

We hope to have shown by this plan for a German artificial earth satellite that it is possible for the Federal Republic to participate actively in the exploration of space and the great commercial possibilities offered by space travel. It is to be expected that the construction of this first satellite will be considered as proof of technical capability, and will result in good industrial publicity for the Federal Republic. It will also eliminate the danger of nonparticipation in the development of new technologies and techniques (Figure 8).

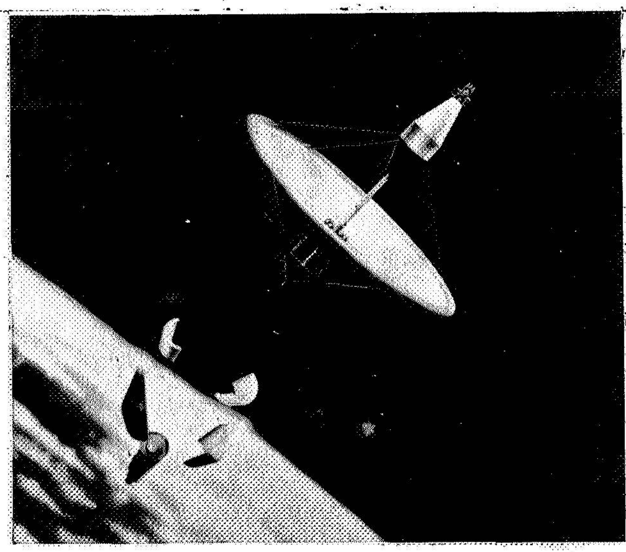

Figure 8. The Satellite in Orbit

Manuscript received May 6, 1963. Lecture before the Third European Space Travel Congress, Stuttgart, May 1963. DGRR Preprint Nr. 1520(63).

Translated for the National Aeronautics and Space Administration by John F. Holman and Co. Inc.